ISSN: 2637-7721

Journal of Plant Biology and Crop Research

Open Access | Research Article

Assessments of Climate Change Adaptation Measures on Agro-climatic Indices and Productivity of Late Planted Rapeseed in Nepalese Mid-Hills

Maniksha Acharya[1]; Lal Prasad Amgain[2]*; Subodh Khanal[1]; Sharoj Raj Mishra[1]; Abhisek Shrestha[3]

[1]Department of Agri-Botany and Ecology, Institute of Agriculture and Animal Science, Tribhuvan University, Nepal.

[2]Faculty of Agriculture, Far-Western University, Nepal.

[3]National Sugarcane Research Program, Jitpur, Nepal Agricultural Research Council, Nepal.

***Corresponding Author(s): Lal Prasad Amgain**

Faculty of Agriculture, Far-Western University, Nepal.

Email: amgainlp@gmail.com

Received: Jul 21, 2021

Accepted: Aug 30, 2021

Published Online: Aug 31, 2021

Journal: Journal of Plant Biology and Crop Research

Publisher: MedDocs Publishers LLC

Online edition: http://meddocsonline.org/

Keywords: Agro-climatic indices; Adaptation measures; Climate change; Productivity; Rapeseed.

Abstract

A combined study of survey cum field experiment on late planted rapeseed (*Brassica campestris* var toria) at Kaski was accomplished during October 2018 to July 2019 in Nepalese mid-hills to access the evidences of climate change and the effect of climate change adaptation measures on phenology, agro-climatic indices and productivity of rapeseed. The Mann-Kendell trend analysis of 1990-2018 showed an increasing trend of average temperature by 0.04ºC year^{-1}, relative humidity by 0.206% year^{-1} and decreasing trend of annual precipitation by 29.289 mm year^{1}. A greater number of farmers were found to be adopting adjustment in planting time, changing of crop cultivars, balanced fertilization and conservation agriculture practices like use of crop mulching as a climate change strategy in the mid-hills of central Nepal. To cope these adverse climatic anolamies, climate change adaptation measures viz. changing crop varieties, conservation agriculture practices, and Farm Yard Manure (FYM) were tested through a field experiment with six diverse cultivars of rapeseed i.e. Preeti, Unnati, Morang Tori 2, Pragati, Bikash and Local with three nutrient management options i.e. use of Farm Yard Manure @5.0 Mt ha^{-1}, N:P:K:S @80:60:40:20 kg ha^{-1} as balanced fertilization, and mulching @6.0 Mt ha^{-1} under strip-plot design having three replications. The highest (799.5) Growing Degree Days (GDD) was recorded for Local cultivar under mulched condition, whereas the lowest (652.1) GDD was recorded for Morang Tori 2 on applying FYM. The results further exerted that highest seed yield (1096.4 kg ha^{-1}) obtained for Morang Tori-2 under mulching was significantly superior over Bikash under balanced fertilization (635.7 kg ha^{-1}). The significantly higher value (6.64) of Heat Use Efficiency (HUE) was found

Cite this article: Acharya M, Amgain LP, Khanal S, Mishra SR, Shrestha A. Assessments of Climate Change Adaptation Measures on Agro-climatic Indices and Productivity of Late Planted Rapeseed in Nepalese Mid-Hills. Plant Biol Crop Res. 2021; 4(2): 1037.

in Pragati, while the lowest (6.499) HUE was recorded with Bikash under balanced fertilization. Therefore, it is suggested that use of improved varieties of rapeseed either with mulching or balanced fertilization would be the productive and profitable climate change adaptation measures for rapeseed under delayed planting in Nepalese mid hills.

Introduction

Rapeseed crops are the third most important crop after cereals and legumes in both area and production in Nepal because it occupies about 80% of the total area among oilseed crops [1]. The total area under rapeseed in Nepal is 160,352 ha with total production of 159,710 Mt and with the least productivity of 0.996 Mt ha^{-1} [2]. The productivity of rapeseed is 0.748 Mt ha^{-1} ha in Kaski district [3] which is quite low compared to the national average of 0.996 Mt ha^{-1} in Nepal [2]. In mid-hills rapeseed is cultivated right after harvesting of rice [4] and same pattern is followed in Pokhara as it is cultivated after harvesting of rice on November (Caritas Nepal, 2019). Under this circumstance, sowing of rapeseed is delayed which effects the growth and yield of rapeseed mainly due to decreasing temperature during flowering and rising temperature during silique formation and seed filling stage [5]. Irrespective to the crops and varieties it is reported that the productivity declines primarily due to the shortening of vegetative and reproductive phase and it is true to the rapeseed too [6]. High temperature stress (>25°C) either develops into parthenocarpic fruits or aborted on the stem in Brassica family [5].

Climate change has been observed in Nepal in diversified topography and vegetation [7,8]. There are several evidences on impact of climate changes on major crops grown in Terai, mid-hills, mountains and Himalayas of Nepal. It has also been addressed that if the issues of climate changes are managed timely there will be the possibilities of coping climate change to maintain the food security and reduction of poverty [7]. Bartlett et al., [9] have anticipated that temperature would increase by 0.5 to 2 ^{0}C by 2030 and also have predicted wide range of change of mean annual precipitation. Agro-climatic indices rely on the daily weather data (Hyhoe & Lapen, 2000) and these agroclimatic indices such as Growing Degree Days (GDD) heat use efficiency (HUE) and pheno-thermal index have been reported to be useful in predicting the growth and yield of crops (Jones et al., 2003). Sikdar [10], Rao et al., (1999) & Rao and Singh (2007) have reported the influence of temperature on phenology and yield of crops. Therefore, these temperature based agro-climatic indices will be pre- requisite to understand phenology and to adjust cropping time over spatial and temporal variations [11].

To cope the negative effect of climate change for late sown crop cultivars, conservation agriculture techniques like use of FYM, balanced fertilization and residue mulching are advocated [12,13]. It is reported that residue mulching moderates the soil temperature variation that happens in the late planted chilled environment [12] which is also a viable option to retain soil moisture and nutrients as organic mulch is considered poor conductor of heat that moderates soil temperature, maintain soil moisture and increases soil fertility [14]. Growing drought resistant crop cultivars, use of organic mulching through crop residue and balanced fertilization are considered the best options and suggested as a strategic climate change adaptive practices adopted worldwide [13,15]. Similar strategic climate change adaptation measures are being practiced in Terai regions of Nepal [16] and worldwide for varieties of major crops [17,18] but not tested in mid-hills of central Nepal. Therefore, this survey cum field experimentation on late planted rapeseed (*Brassica campestris* var toria) at Puranchaaur, Kaski, Nepalese mid-hills was accomplished to access the evidences of climate change and the effect of climate change adaptation measures on phenology, agro-climatic indices and productivity of rapeseed.

Materials and method

A purposive sampling survey with 40 HHs were conducted to know the climate change adaptation measures practiced by farmers for climate change adaptation in Puranchaur, Kaski supplemented with field experimentation and meteorological data from October 2018 to July 2019. The daily weather data records were collected from the Department of Hydrology and Meteorology, Pokhara of last 29 years (1990-2018). These data were analyzed using Mann-Kendell test in XLSTAT [19].

$$S = \sum_{k-1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

Where, $x_1, x_2 \dots \dots x_n$ represents n data points and x_j represents data point at j time.

To assess the agro-climatic indices and crop productivity of late planted rapeseed (*Brassica campestris* var. toria) various climate change adaptation measures were tested and agro-climatic indices were measured. The daily mean temperature attained by the various rapeseed varieties from sowing to physiological maturity has been recorded and depicted in Figure 1. In addition to this survey, a field experimentation was conducted with six cultivars of rapeseed i.e. Preeti, Unnati, Morang Tori-2, Pragati, Bikash and Local and three nutrient management options i.e. use of Farm Yard Manure @5 Mt ha^{-1}, N:P:K:S @80:60:40:20 Kg ha^{-1}, and mulching @6 Mt ha^{-1} in a strip-plot design having three replications. Rapeseed cultivars were grown using package of practices (Lal, 2016). The average temperature from one development stage to other stage of a particular rapeseed cultivar was taken for the further mathematical expressions to calculate the agro-climatic indices using the following formula [20,21].

1. Growing degree days (GDD)= {(Tmax+Tmin)÷2}-Tb

(Tb is the minimum temperature at which seed will germinate and is estimated to be 4.0 degree Celsius for Brassica species (Luo et al., 2011)

2. Heat use efficiency (HUE)= Biomass yield (kg/ha) ÷ GDD

3. Pheno-thermal Index (PTI)= GDD÷ Growth days

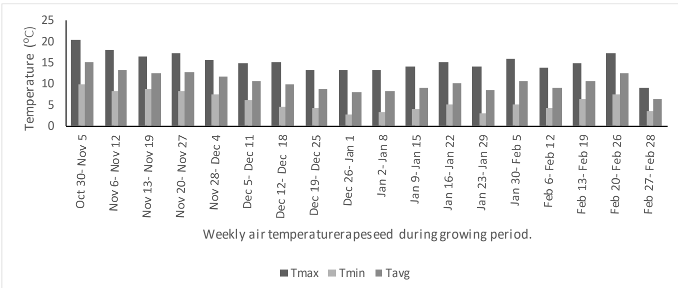

Figure 1: Average temperature during growth period of different varieties of rapeseed.

Note: Source: DHM, Pokhara.

The various survey and experimental data recorded mainly on farmer's performance ranking and crop phenology, growth and yield attributes and yield were subjected to statistical analysis using MS-Excel, and Genstat 18th edition respectively. An analysis of variance and LSD mean separations was done from the reference of Gomez and Gomez [22]. ANOVA was calculated to test the significance of difference for each parameter. Calculation of the significant critical differences at 5% level of significance was made by mean comparisons.

Results and discussion

Trend analysis of different climatic parameters (1990-2018)

Trends in the observed climate data for the base line period (1990-2018) over the period of 29 years were analyzed using the Mann Kendall (MK) test for understanding the significance in the trends for mean annual temperature, precipitation and relative humidity (Figure 2-4). The result showed that there existed a significant increasing trend of temperature in central mid-hills (Figure 2). Similarly, the highest precipitation (3000 mm year^{-1}) was recorded in the year 2018 over the period of analysis (Figure 3). The district wise trend values of annual precipitation showed decreasing trend significantly in Kaski [23]. There was an increase of mean relative humidity by 0.206 % per year as per the trend line as indicated in Figure 4 over the period of analysis. The lowest relative humidity was recorded in 1994 (57%), 1999 (58%), 2010 (60%) and 2016 (63%) which indicates the driest years over the period of analysis.

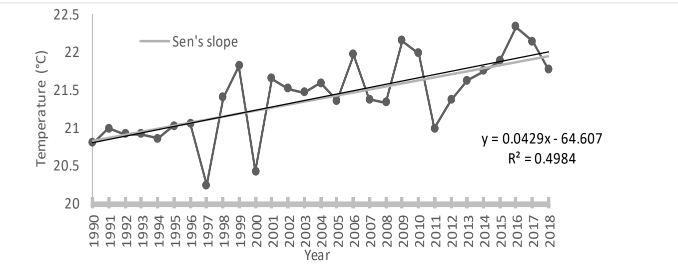

Figure 2: Trend analysis of mean annual temperature of Pokhara.

Note: Source: DHM, Pokhara.

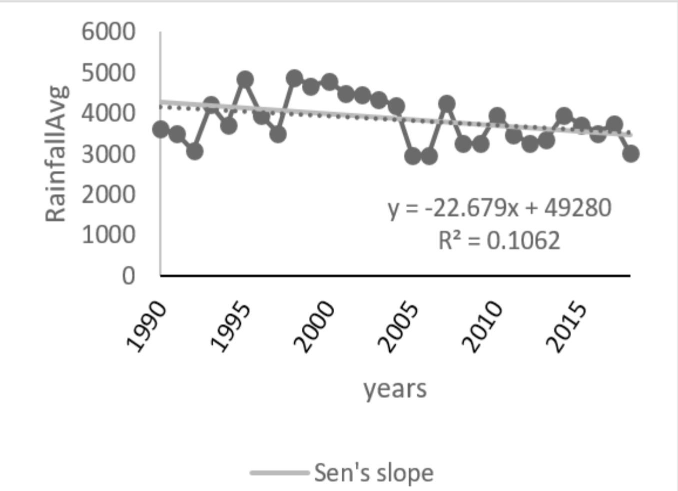

Figure 3: Trend of Average annual rainfall.

Note: Source: DHM, Pokhara.

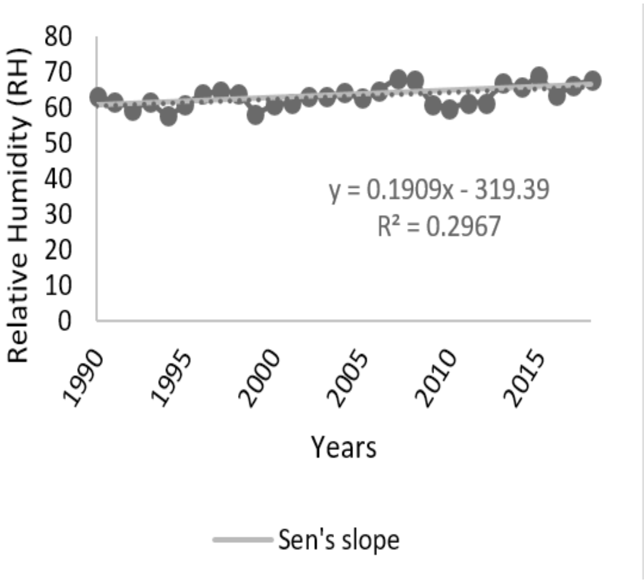

Figure 4: Trend of mean relative humidity.

Note: Source: DHM, Pokhara.

On farm adaptation practices in rapeseed crops

A number of practices that has been used in recent years to adapt to climate changes have been reported during farmer's group discussion and household survey (Table 1). These were: adjustment in planting time, change in crop varieties, conservation agriculture practices (mulching), and high input use of fertilizers, water management and traditional way of using farm yard manures in their farms. This analysis showed a significant higher number of farmers were using farm yard manure. In addition, a greater number of farmers were adopting adjustment in planting time, changing of crop cultivars and conservation agriculture practices like use of mulching. These are widely used practices in agriculture among the farmers in many parts of the world [24-26].

Table 1: On farm adaptation practices in rapeseed crop (n=40).

Adaptation Practices	Yes	No	P value
Adjustment in planting time	32	18	0.047
Change in crop cultivars	29	21	0.25
Water management	12	38	0.00
Conservation agriculture practices (Mulching)	28	22	0.39
High input of chemical fertilizers	20	30	0.15
Traditional ways of using FYM	35	15	0.00

Note: Household survey, 2019.

Phenology of rapeseed cultivars

Thermal units were used for describing the temperature responses to growth and different pheno-phases as the life cycle of rapeseed crop. The occurrence of different phenological stages was found to be affected due to different nutrient management options (Table 2). The phenological phases such as emergence (P1) first flower appearance (P2), 50% flowering (P3), 100% flowering (P4), seed filling stage (P5) and physiological maturity (P6) found to be decreased appreciably with other nutrient management options other than mulching. Delay in first flower appearance was observed in Preeti, Local and Unnati cultivars. The flowering appearance of both cultivars i.e. Local and Unnati was on same date when they were managed under different nutrient management options. This stage was earlier by 7-9 days in Bikash, Morang Tori-2 and Unnati as compared to other varieties under FYM application and balanced fertilization. The number of days required to attain different thermal environments might be due to their genetic characters. Increase in soil temperature and moisture content stimulate root growth which leads to greater plant growth under mulched treatment [27]. The longest period taken for maturity was recorded under sesame straw and the lowest was recorded in no mulch condition. Mulch material had an influence on reducing environmental stress such as water stress by conserving moisture that serves for plant to facilitate growth and development [28].

Growing degree days and pheno-thermal index at physiological maturity stages

Amongst the interaction of nutrient management and cultivars, the highest Growing Degree Day (GDD) requirement was observed in Local (788.5°C) under mulched condition, whereas the lowest values of GDD for Morang Tori- 2 (652.1°C) on applying FYM. The higher value of GDD was recorded for Local cultivar at physiological maturity stage (Table 3). For all the cultivars and nutrient management options, the development stages showed the increasing trend of heat units. GDD was comparatively higher for mulching than other nutrient management options which is in accordance with Zhang et al. [29] who reported that mulching increases the accumulated GDD in low temperature areas and allow the crop to mature sooner than the crop under un-mulched condition. Application of FYM decreased the calendar days to phenology of rapeseed as compared to normal mulching due to fluctuated unfavorable temperature.

Table 2: Phenology of rapeseed cultivars under different nutrient management options in Puranchaur, Kaski.

Cultivar	Fertilizer	P1	P2	P3	P4	P5	P6
Preeti	Mulching@5Mt/ha	5	46	58	72	90.0^{h}	114.7^{hi}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	6	46	59	74	90.33^{h}	114.0^{gh}
	FYM@6Mt ha^{-1}	6	51	61	75	95.67^{i}	119.0^{j}
Local	Mulching@5Mt/ha	7	46	59	74	91.67^{i}	116.0^{i}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	7	44	58	72	89.33^{h}	112.7^{g}
	FYM@6Mt ha^{-1}	8	42	56	70	95.67^{j}	119.0^{f}
Unnati	Mulching@5Mt/ha	6	46	55	71	98.67^{k}	109.0^{f}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	7	46	53	67	85.67^{f}	106.7^{e}
	FYM@6Mt ha^{-1}	8	44	52	68	87.67^{g}	106.3^{e}
Bikash	Mulching@5Mt/ha	5	39	54	67	81.0^{c}	102.0^{c}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	6	38	54	68	82.0^{cd}	105.0^{d}
	FYM@6Mt ha^{-1}	6	36	52	67	82.67^{de}	102.0^{c}
Morang Tori-2	Mulching@5Mt/ha	6	30	39	51	83.33^{e}	108.0^{f}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	7	32	41	50	82.0^{cd}	105.0^{d}
	FYM@6Mt ha^{-1}	7	33	42	48	81.33^{c}	102.0^{c}
Pragati	N:P:K:S@80:60:40:20 Kg ha^{-1}	6	40	49	62	78.33^{b}	96.0^{b}
	FYM@6Mt ha^{-1}	8	39	47	60	76.33^{a}	96.3^{b}
LSD **(0.05)** **CV (%)**	N:P:K:S@80:60:40:20 Kg ha^{-1}	7 NS 14.7	37 NS 8.6	44 NS 5.0	58 NS 5.3	75.67^{a} 1.09^{**} 0.8	93.0^{a} 1.29^{*} 0.8

Note: P1 "Emergence"; P2 "First flower appearance"; P3 "50% flower appearance"; P4 "100% flower appearance"; P5 "Seed filling" and P6 "Physiological maturity"
Significant at 1% level of significance "**"; Significance at 5% level of significance "*"
Means in a column followed by same letter (s) are not significantly different

Table 3: Calendar days and agro-climatic indices of various rapeseed cultivars grown under different nutrient management options in Puranchaur, Kaski.

Cultivars	Nutrient management	Calendar days	GDD	PTI
Preeti	Mulching@5Mt/ha	111.7^{g}	775.5^{hi}	1.334^{cde}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	114.0^{gh}	747.0^{g}	1.276^{cde}
	FYM@6Mt ha^{-1}	112.0^{g}	744.5^{g}	1.166^{abc}
Local	Mulching@5Mt/ha	113.0^{i}	788.5^{i}	1.218^{bcd}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	112.7^{g}	737.2^{g}	1.129^{abc}
	FYM@6Mt ha^{-1}	119.0^{f}	767.2^{h}	1.161^{abc}
Unnati	Mulching@5Mt/ha	106.0^{e}	700.5^{f}	1.460^{ef}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	109.7^{e}	707.5^{f}	0.938^{a}
	FYM@6Mt ha^{-1}	102.3^{f}	778.5^{hi}	1.401^{def}
Bikash	Mulching@5Mt/ha	106.0^{d}	673.6^{c}	1.460^{ef}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	105.0^{d}	677.8^{cd}	0.938^{a}
	FYM@6Mt ha^{-1}	102.0^{c}	666.7^{c}	1.401^{def}
Morang Tori -2	Mulching@5Mt/ha	102.0^{c}	657.2^{abcd}	1.630^{fg}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	105.0^{d}	653.6^{abcd}	1.284^{cde}
	FYM@6Mt ha^{-1}	108.0^{f}	652.1^{abc}	1.235^{bcde}
Pragati	Mulching@5Mt/ha	96.0^{b}	664.0^{d}	1.755^{g}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	96.3^{b}	659.5^{abcd}	1.477^{ef}
	FYM@6Mt ha^{-1}	93.0^{b}	659.4^{abcd}	1.359^{cde}
LSD		1.296*	9.366**	0.136**
CV(%)		0.8	0.8	5.6

Note: Significant at 1% level of significance "**"
Means in a column followed by same letter (s) are not significantly different.

Heat use efficiency and yield of rapeseed varieties under different nutrient management options

The highest grain yield (1096.4 kg ha^{-1}) was obtained in Morang Tori-2 at mulched condition which was statistically at par with Pragati (1067.9 kg ha^{-1}) and Preeti (1034.3 kg ha^{-1}) and significantly superior over the Bikash under balanced fertilization treatment (635.7 kg ha^{-1}). The significantly higher values for heat use efficiency were found in Pragati (6.640), while the lowest was recorded with Bikash cultivar under balanced fertilization (Table 4). Higher value of HUE could be due to the higher value of rapeseed yield. As temperature was optimum throughout the growing period, it utilized heat more efficiently and increased biological activity that confirms higher yield. Optimum temperature and short calendar days received by Pragati cultivar resulted higher rapeseed yield via optimum metabolic activity thereby higher HUE which is in accordance with Gupta et al., [30]. Eruola et al. [31] suggested that mulching reduces the amount of radiant flux reaching the soil surface and minimizes heat by evaporations. Mulching significantly improves soil temperature, emergence and development. It decreases maximum soil temperature and conserves moisture which helps in increase of yield [31]. Mulching has significant effect on seed yield of rapeseed cultivars. Sarangi et al. (2010) had a significant effect on yield of rapeseed cultivars and reported 35.4% increase in yield due to mulching over non-mulched control condition. Rautaray [32] reported significant result indicating about 16% increase in mustard yield due to rice straw mulching over without mulch treatments. The legume straw mulch provided about 1297 kg ha^{-1} mustard yield and paddy straw mulch recorded 1357 kg ha^{-1}, which were significantly higher over no mulch (1154 kg ha^{-1}) treatments. The increase in grain yield of mustard was due to more dry matter production and increases in most yield attributing characters of the crop [33]. The values of HUE showed varied trends at different nutrient management options for each.

Table 4: Heat use efficiency and yield of rapeseed cultivars under different nutrient management options at Puranchaur, Kaski.

Cultivars	Nutrient management	HUE (kg/ °C day)	Grain yield (kg ha^{-1})
Preeti	Mulching@5Mt/ha	6.609^{bcd}	1034.3^{ij}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	6.533^{abc}	953^{fghi}
	FYM@6Mt ha^{-1}	6.530^{abc}	868.3^{cdefg}
Local	Mulching@5Mt/ha	6.626^{cd}	960.6^{ghi}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	6.595^{abcd}	832.2^{cd}
	FYM@6Mt ha^{-1}	6.594^{abcd}	891.2^{defgh}
Unnati	Mulching@5Mt/ha	6.515^{ab}	920.4^{defgh}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	6.526^{abc}	790.3^{bc}
	FYM@6Mt ha^{-1}	6.530^{abc}	722.8^{ab}
Bikash	Mulching@5Mt/ha	6.517^{ab}	883.1^{hi}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	6.499^{a}	635.7^{a}
	FYM@6Mt ha^{-1}	6.601^{abcd}	934.4^{fgh}
Morang Tori -2	Mulching@5Mt/ha	6.572^{abcd}	1096.4^{j}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	6.536^{abcd}	875.7^{defg}
	FYM@6Mt ha^{-1}	6.521^{abc}	861.8^{cdef}
Pragati	Mulching@5Mt/ha	6.640^{d}	1067.9^{j}
	N:P:K:S@80:60:40:20 Kg ha^{-1}	6.595^{abcd}	928.8^{efgh}
	FYM@6Mt ha^{-1}	6.594^{abcd}	842.9^{cde}
LSD		0.058**	95.25**
CV (%)		0.5	5.1

Note: Significant at 1% level of significance "**"
Means in a column followed by same letter (s) are not significantly different.

Conclusions

There are evidences of increments in mean monthly average and annual temperature from 1990-2018 at Puranchaur, Kaski, mid-hills of Central Nepal. The rapeseed growing farmers were aware on the effects of climate change and their adaptation strategies such as change of crop cultivars, traditional way of using FYM and conservation agriculture practices such as mulching as most of the farmers are adopting these practices in growing mustard. All cultivars and nutrient management options exhibited the earlier development phases/ stages with the increasing trend of heat units. Agro-climatic indices like GDD was comparatively higher for mulching than other nutrient management options. Pragati and Morang Tori-2 cultivars showed greater stability to Heat Use Efficiency (HUE) than other cultivars. Application of FYM decreased the calendar days to physiological maturity of rapeseed as compared to normal mulching. However, additional work is needed further to evaluate the impacts of the potential changes in agro-climatic indices and crop yields for themed-hill agro-eco-region of central Nepal.

Acknowledgements

The authors are grateful to College of Natural Resources and Management (CNRM), Puranchaur Kaski for providing research field. The B Sc Ag students of CNRM are equally acknowledged for their helps in the field preparation and data collections.

References

1. Ojha RB. Nitrogen-Sulphur use economics in rapeseed productivity at Rampur, Chitwan, Nepal. Advances in Plants & Agriculture Research. 2018.
2. MOAD. Statistical Information on Nepalese Agriculture. Government of Nepal. Agriculture Information and Communication Centre, Hariharbhawan, Lalitpur. 2017.
3. MOAD. Statistical Information on Nepalese Agriculture. Government of Nepal. Agriculture Information and Communication Centre, Hariharbhawan, Lalitpur. 2014.
4. Gadal N, Shrestha J, Poudel M, Pokhrel B. A review on production status and growing environments of rice in Nepal and in the world. Archives of Agriculture and Environmental Science. 2019; 4: 83-87.
5. Young LW, Ron W, Wilen P, Bonham-Smith C. High temperature stress of Brassica napus during flowering reduces micro- and mega gametophyte fertility, induces fruit abortion, and disrupts seed production, Journal of Experimental Botany. 2004; 55: 485-495.
6. Sidlauskas G, Bernotas S. Some factors affecting seed yield of spring oilseed rape (Brassica napus L.). Lithuanian Institute of Agriculture. Agronomy Research. 2003; 1: 229-243.
7. Paudel MN. Effect of climate change on food production and its implication in Nepal. Agronomy Journal of Nepal. 2010; 1: 40-49.
8. Paudel MN. Adaptation mechanisms in agriculture for climate change in Nepal. Hydro Nepal, Special issue. 2012; 82-85.
9. Bartlett R, Bhattarai L, Pant D, Hosterman H, McCornick P. Climate change impacts and adaptation in Nepal. Colombo, Srilanka: International Water Management Institute. 2010; 3.
10. Sikder S. Accumulated heat unit and phenology of wheat cultivars as influenced by late sowing heat stress condition. J Agric Rural Dev. 2009; 7: 57-64.
11. Sreenivas G, Reddy MD, Raji D. Agro-meteorological indices in relation to phenology of aerobic rice. Journal of Agro-meteorology. 2010; 12: 241-244.
12. Amgain LP, Sharma AR, Timsina J, Wagle P. Water, nutrient, and energy use efficiencies of no-till rainfed cropping systems with or without residue retention in a semi-arid dryland area. Global J. Agriculture and Allied Sciences. Nepalese Agricultural Professionals in America. 2019; 1: 30-42.
13. Amgain LP, Sharma AR, Timsina J, Shrestha A. Assessments of the productivity and profitability of diverse crops and cropping systems as influenced by conservation agriculture practices under a semi-arid rainfed environment of western India. ANADOLU Journal of Agricultural Sciences. 2020; 35: 469-482.
14. Vaidya VB, Varshneya MC, Bote NL, Naidu JRV. Estimation of thermal efficiency and apparent reflectivity of mulches using soil temperature. J Mah Agric Univ. 1995; 20: 341-344.
15. Lal M, Bhati DS, Nag AK. Economics and production potential of different cropping sequence on farmers field, Journal of Eco-Physiology. 2004; 7: 143-145.
16. Amgain LP. Agro- meteorological indices in relation to phenology and yields of promising wheat cultivars in Chitwan, Nepal. Journal of Agriculture and Environment. 2013; 14: 111-120.
17. Malla G. Climate change and its impacts on Nepalese Agriculture. The journal of Agriculture and Environment. 2008.

18. Penalba EH. Adaptation to Climate Change among Farmers in Bulacan, Philippines. The Journal of Rural and Community Development. 2019; 14: 1-23.

19. Gilbert RO. Statistical Methods for Environmental Pollution Monitoring, Wiley, NY. 1987.

20. Rao AS, Singh RS, Joshi NL, Ramakrishna YS. Evapo-transpiration, water and radiation-utilization of cluster bean (Cyampsis tetragonoloba). Indian J. Agric. Sci. 2000; 70: 149-153.

21. Singh RS, Joshi NL, Singh HP. Pearl millet phenology and growth in relation to thermal time under arid environment. Journal of Agronomy and Crop Science. 1998; 180: 83-91.

22. Gomez KA, Gomez AA. Statistical procedures for agriculture research. John Wiley and Sons, New York, USA. 1984.

23. DHM. Observed Climate Trend Analysis in the Districts and Physiographic Regions of Nepal (1971-2014). Department of Hydrology and Meteorology, Kathmandu. 2017.

24. Cleveland DA, Soleri D, Smith SE. Do folk crop varieties have a role in sustainable agriculture. Bio Sciences. 1994; 44: 740-751.

25. Risbey J, Kandlikar M, Dowlatabadi H. Scales, context and decision making in agriculture adaptation to climate variability and change. Mitigation and Adaptation Strategies for Global Change. 1999; 4: 137-165.

26. Salinger MJ, Silvakumar MVK, Motha R. Reducing Vulnerability of Agriculture and Forestry to Climate Variability and Change: Workshop Summary and Recommendations. Increasing Climate Variability and Change. 2005: 341-352.

27. Bhardwaj RL, Meena CB, Singh N, Ojha SN, Dadhich SK. Annual progress report of Krishi Vigyan Kendrs, Sirohi, MPUAT Udaipur. 2011; 45-46.

28. Teame G, Tsegay A, Abrha B. Effect of organic Mulching on Soil moisture, yield, and Yield Contributing Component of sesame (Sesamum indicum). International Journal of Agronomy. 2017.

29. Zhang F, Zhang W, Qi J, Li FM. A regional evaluation of plastic film mulching for improving crop yields on the Loess Plateau of China. 2018; 458-468.

30. Gupta V, Singh M, Kumar A. Performance of different weed management treatments on heat use efficiency of chickpea crop (Cicer arietinum) under rainfed condition of Jammu. Indian Journal of Agricultural Sciences. 2014; 84: 1082-1087.

31. Eruola AO, Bello NJ, Ufoegbune GC, Makinde AA. Application of RainfallPotential Evapo-transpiration Model for Determining Optimum Planting Date of Yam (Dioscorea rotundata) in a Tropical Wet-and-Dry Climate. International Journal of Plant Research. 2012; 2: 36-40.

32. Rautaray SK. Effect of mulching on yield and economics of rainfed rice (Oryza sativa) - based cropping sequence in lower Assam. Indian Journal of Agronomy. 2005; 50: 13-15.

33. Singh AK, Singh RR, Singh AK, Singh PK. Influence of dates of sowing and irrigation scheduling on growth and yield of mustard (Brassica juncea L). International Journal of Farm Sciences. 2014; 4: 80-85.

34. Luo T, Khan MN. Estimation of Base Temperature for Germination of Rapeseed (Brassica napus) using Different Models. International Journal of Agriculture and Biology. 2011; 20: 524-530. http://doi.org/10.17957/IJAB/15.0512.

35. Singh RS, Joshi NL, Singh HP. Pearl-millet phenology and growth in relation to thermal time under arid environment. Journal of Agronomy and Crop Science. 1998; 180: 83-91.